A Novel High Power LED Module Design on Aluminum Board (COAB) by Packaging Multi-Die in both Series and Parallel

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Abstract. To decrease the LED operating temperature this paper presents a novel high power LED COAB (Chip on Aluminum Board) bonding method, the heat dissipation performance was studied by packaging the multi-die in the combination of series and parallel. The trade-off parameters were the bonding distance and driving voltage. The dies were connected in a combination of 3 dies in series and 3 sets in parallel (3x3 square matrix pattern). If the separation distance of die bonding was 1.5mm, the temperatures on the top surface of center LED with driving voltage of 8 (9) Volts was 75.2 (90.5) ℃. On the other hand, if the separation distance reduced to 1.0mm with the driving voltage of 8 (9) Volts, then the temperatures at the top surface of center LED would be increased to 75.7 (115.2) ℃. Thus for the LEDs efficiency kept at 80％ of those at 25℃, the final choice of die bonding distance and driving voltage were 1.0mm and 8V, respectively.

Introduction

The LED has several advantages, such as low power dissipation and long term reliability. Thus it can replace the traditional light bulb for illumination [1-2]. But as the applying power to the LED is increased, the heat dissipation problem would reduce the efficiency dramatically [3-4]. The LED is useless when the efficiency is reduced to 70% [5-6]. The efficiency will be decreased as the working temperature increased and times go by. The LED is extensively applied in the area of illumination right now, especially in the fields of high power RGB white LED illumination. So the thermal dissipation problem should be solved. The factors that affect the efficiency of thermal dissipation problem are as LED chip, carrier substrate, die packaging material and method.

This paper presents a novel high power LED COAB (Chip on Aluminum Board) bonding method, because not only the heat dissipation path of bonding the chip on board but the thermal resistance of aluminum substrate can be reduced to increase the efficiency. Besides, COAB technology could simplify the circuit design and also reduce the cost. The heat dissipation performance was studied by packaging the multi-die in the combination of series and parallel. The trade-off parameters were the bonding distance and driving voltage. The dies were connected in a combination of 3 dies in series and 3 sets in parallel (3x3 square matrix pattern). If the separation distance was 1.5mm, the temperatures on the top surface of center LED with driving voltage of 8 (9) Volts was 75.2 (90.5) ℃. On the other hand, if the separation distance reduced to 1.0mm with the driving voltage of 8 (9) Volts, then the temperatures at the top surface of center LED would be increased to 75.7 (115.2) ℃. Thus for the LEDs efficiency kept at 80％ of those at 25℃, the final choice of die bonding distance and driving voltage were 1.0mm and 8V, respectively.The other contains of this paper are as follows: the second section is for the thermal dissipation problem. Section 3 briefs the experiments and procedures. The final section is conclusion.

Thermal Dissipation Problem

The In general, the working temperature of LED p-n junction is 25℃, and the efficiency is normalized as 100％. When the working temperature is increased to 75℃, then the efficiency would be decreased to 80％, and even lowering to 40％ as the temperature is 175℃. Thus the LED efficiency and life-cycle are inversely proportional to the working temperature.

In general, if the efficiency to dissipate the heat generated by the LED is lower, then its p-n junction temperature would be increased, and so does the LED efficiency be decreased in the next moment, and finally the LED reliability, lighting efficiency and performance would be faded quickly. Fig. 1 shows the relationship of LED efficiency and its junction temperature, if the junction temperature is increased from 25℃ to 100℃, then the efficiency of each kind of LED would be reduced from 20% (white) to 75% (yellow LED). Besides, Fig. 2 shows that the LED life-cycle is also inversely proportional to its working temperature, and when the working temperature is increased from 63℃to 74℃, the average life-cycle (for lighting efficiency: 70%) would be reduced by 25%.

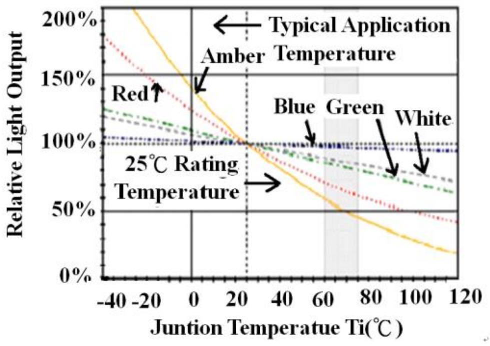


Figure 1. Relationship of LED efficiency and junction temperature

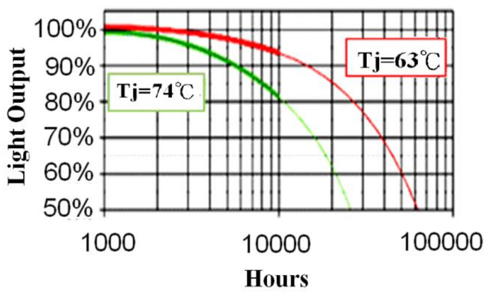
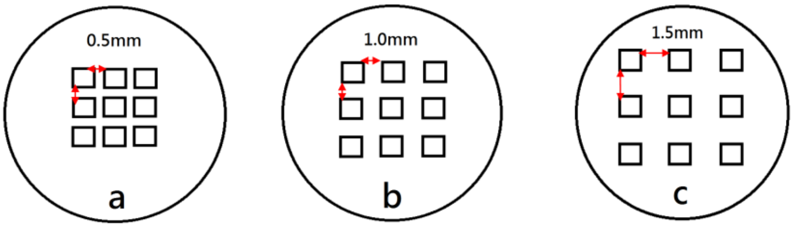


Figure 2. Relationships of LED life-cycle, light efficiency and working temperature

In this paper the COAB (Chip On Aluminum Board) package technology was applied to package LED chip, because not only the heat dissipation path of bonding the chip on board but the thermal resistance of aluminum substrate can be reduced to increase the efficiency. Besides, COAB technology could simplify the circuit design and also reduce the cost.

Experiments and Procedures

An aluminum substrate (33mm×33mm×1.5mm) with better heat dissipation performance was applied as the substrate. The chip (45mils×45mils) was blue LED (450-452 nm) with epi-layer technology. The LED dies were arranged in a 3×3 matrix pattern with 9 LEDs connected in 3 series and 3 parallel. The major topic of this research is to find the better combination of separation range for die bonding and its driving voltage. Three kinds of bonding distance (BD) as shown in Fig. 3 were performed for comparison, such as 0.5, 1.0mm, and 1.5mm. On the other hand, two driving voltages, 8 or 9 Volts, were applied to the LEDs for working point selection. The thermal couple was applied to take temperature measurements at the top and bottom surfaces of the center die and substrate, respectively.



(a) 0.5mm (b) 1.0mm (c) 1.5mm

Figure 3. Three kinds of bonding distance for comparison. (a) 0.5mm, (b) 1.0mm and (c) 1.5mm

Step 1: Chip Bonding. Making three kinds of LED die bonding method as shown in Fig. 3, the separation distance of the die were 0.5, 1.0mm, and 1.5mm, respectively. Then bonding LED dies on the substrate with silver paste, and curing at 150℃ for 30 minutes with hot wind drying in an oven.

Step 2: Wire bonding. Bonding the LED dies with gold wire to the outer lead terminals (substrate kept with temperature 130℃-150℃) as shown in Fig. 4 for inter-connection.

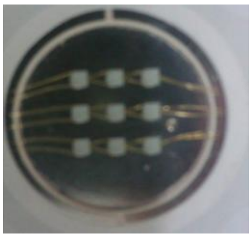


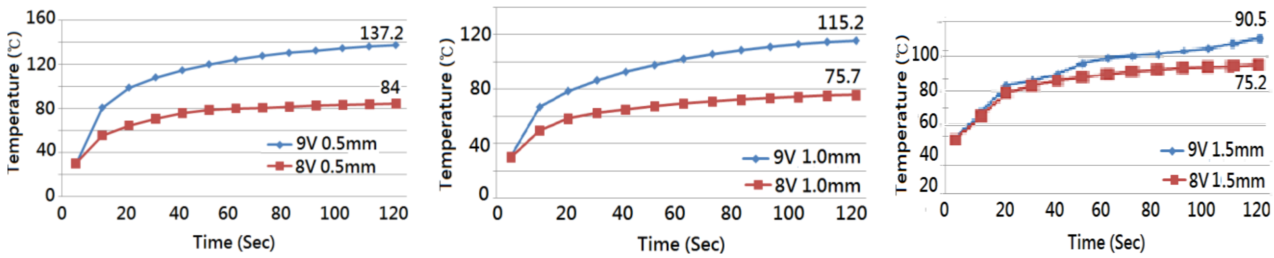
Figure 4. Bonding the chip with gold wire to outer lead terminals for inter-connection

Step 3: Temperature Measurements. Putting the LED dies in a 3×3 matrix pattern with 9 LEDs connected in 3 series and 3 parallel. Set the driving voltage as 8 or 9 Volts for two minutes in order to compare the thermal dissipation performances in equilibrium conditions. Take temperature measurements respectively at the top and bottom surfaces of the center die and substrate.

Step 4: Select the better combination of die bonding distance (BD) and driving voltage (DV). The combinations were listed in Table 1, and the corresponding measurement results were shown in Figs. 5-6. One could see all the temperatures would be approaching constant values at the testing periods of two minutes, and the temperatures applying 9V were larger than those using 8V for the same case.

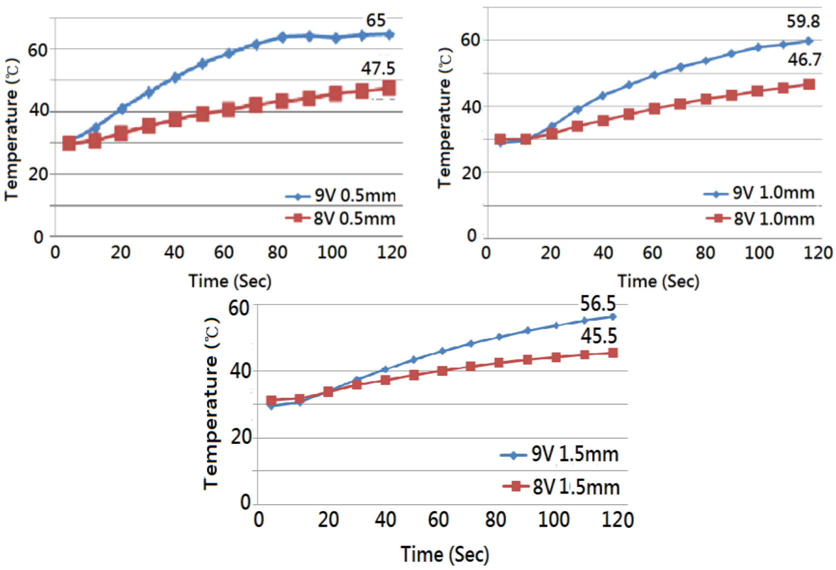
Table 1 Combinations of separation distance for die bonding and driving voltage.

Combinations	Bonding Distance (BD)	Driving Voltage (DV)	Test Point
1 (Fig. 5(a))	0.5mm	9V	Top surface of center die
2 (Fig. 5(b))	1.0mm	9V	Top surface of center die
3 (Fig. 5(c))	1.5mm	9V	Top surface of center die
4 (Fig. 6(a))	0.5mm	9V	Bottom of substrate
5 (Fig. 6(b))	1.0mm	9V	Bottom of substrate
6 (Fig. 6(c))	1.5mm	9V	Bottom of substrate



(a) BD=0.5mm (b) BD=1.0mm (c) BD=1.5mm

Figure 5. Temperature curves on center die surface by applying 8 and 9 Volts. (a) BD=0.5mm, (b) BD =1.0mm, and (c) BD=1.5mm.



(a) BD=0.5mm (b) BD=1.0mm (c) BD=1.5mm

Figure 6. Temperature curves on bottom surface of substrate by applying 8 and 9 Volts. (a) BD=0.5mm, (b) BD=1.0mm, and (c) BD=1.5mm.

Performance Analyses

One could redraw the temperatures (at two minutes) on the top surface of center die versus bonding distances as shown in Fig. 7(a) for easy of comparison. The largest temperature for BD=0.5mm with 9V (8V) is 137.2℃(84℃). The largest temperature for BD=1.0mm with 9V (8V) is 115.2℃(75.7℃). Finally, the largest temperature for BD=1.5mm with 9V (8V) is 90.5℃(75.2℃). Thus, one had the following conclusion. The larger the separation ranges, the lower the temperature, and if applying 9V the temperature with BD=1.5mm was decreased by 46.7℃ for the case with 0.5mm. Thus the separation distance of die bonding is the key parameter for design. Similarly, one could redraw the temperatures on the bottom surface of substrate (at two minutes) versus bonding distances as shown in Fig. 7b). The largest temperature for BD=0.5mm with 9V (8V) is 65℃(47.5℃). The largest temperature for 1.0mm separation with 9V (8V) is 59.8℃(46.7℃). Finally, the largest temperature for 1.5mm separation with 9V (8V) is 56.5℃(45.5℃). Thus, one had the following conclusion. The larger the bonding distances, the lower the temperature, and if applying 9V the temperature with BD=1.5mm was decreased by 46.7℃ for the case with BD=0.5mm. Thus the bonding distance of die is the key parameter for design.

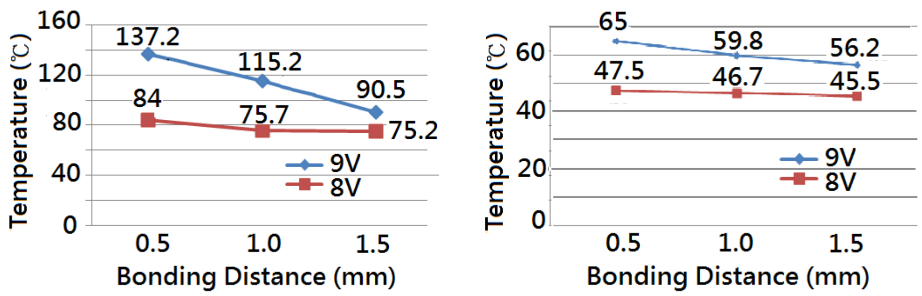


Figure 7. Temperatures vs. BD with 9V and 8V. (a) Top surface of die. (b) Bottom surface of substrate.

Summary

This paper presents a novel high power LED COAB (Chip On Aluminum Board) bonding and heat dissipation performance study, the 9 multi-die were packaged in the combination of 3 dies in series and

3 in parallel. The die bonding distance and driving voltage are the key parameters to tradeoff. The temperatures on the top surface of LED and the bottom surface of substrate by applying 8 and 9 Volts are studied. If the bonding distance and driving voltage are respectively 1.5mm and 8 (or 9) Volts; and then the temperatures on the top surface of LED and substrate of the die can be respectively as 75.2 (90.5)℃ and 45.5 (56.5)℃. On the other hand, if the die bonding distance reduced to 1.0mm with the driving voltage of 8 (9) Volts, then the temperatures at the top and bottom of the LED surface would be increased to 75.7 (115.6) ℃ and 46.7 (59.8)℃, respectively. Thus for the LEDs efficiency kept at 80% of those at 25℃, the final choice of die bonding distance and driving voltage were 1.0mm and 8V, respectively.

Acknowledgements

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